Introduction to Brain & Behavior
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Lecture 6
The Cerebral Cortex

Hello, and welcome to the course introduction to brain and behavior. I am Doctor Ark Verma from IIT Kanpur. This is the second week of the lectures in this course. And today we'll be talking about the cerebral cortex.

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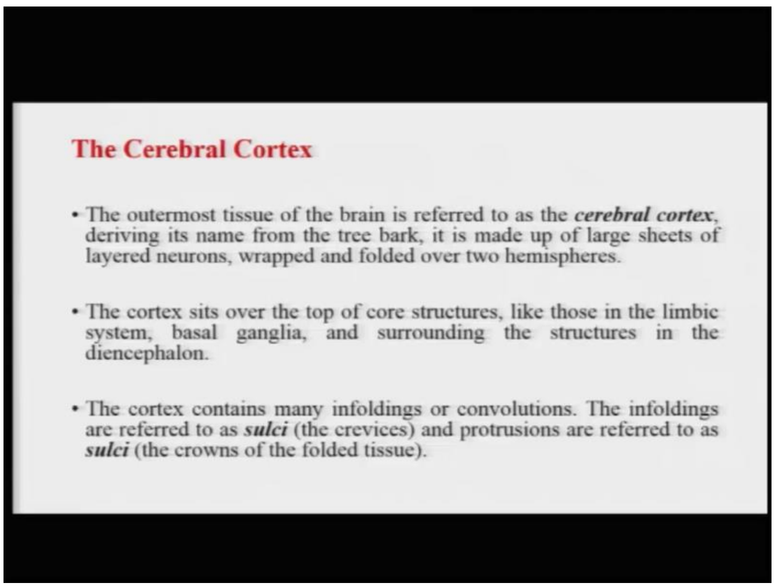

Now, the cerebral cortex is part of the structures that we are discussing at the end of the last week in the final lecture.

The cerebral cortex basically is the outermost tissue of the brain. And it is, it derives its name from the Greek word Bark, basically, which resembles how the tree barks are structured, or say for example, the folds on the bark of the tree. This is very similar to how you've looked at the picture of the brain and we just show you very surely the way the picture of the brain looks like.

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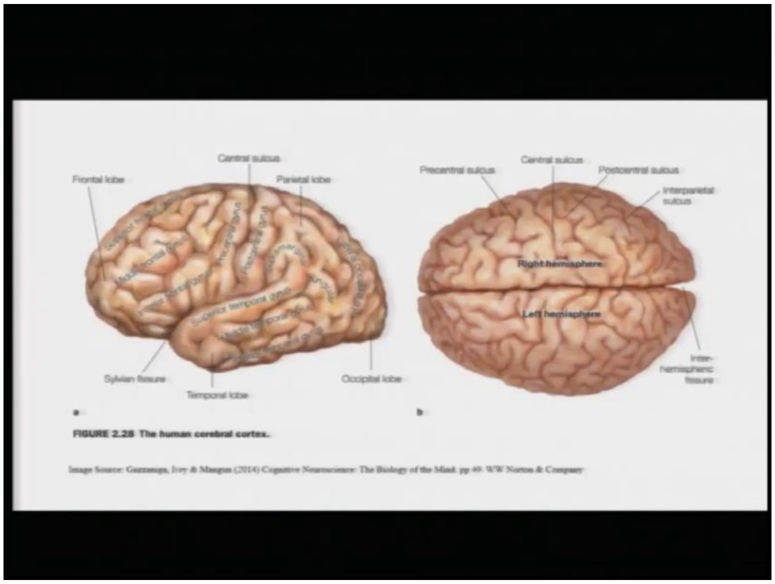

So you can see that this is a set of folded or wrapped convolution of neurons. And you can see that there are so many of these ridges which are called sulci. And then there's these protrusions, which are called gyri, we'll come to that in a bit. But this is where this, the name cerebral cortex actually comes from.

This is the outermost tissue of the brain, and is basically made up of large sheets of layer neurons, which are wrapped and folded over two hemispheres. So also, this is not just one structure. It is basically two halves, which are connected by this, a bunch of fibers called the corpus callosum, we'll talk about them moving further.

So the cortex basically sits over top of core structures, the ones that we saw in the last few lectures, the brain stem, the midbrain, the basal ganglia and other things. And on top of that, this is basically something that is wrapped around on top of these basic structures, which are coming starting from the spinal cord, brain stem and those kinds of things. So, this basically, as I was saying, these, the cortex basically consists of many enfoldings or convolutions as I was saying. And these in foldings are referred to as sulci, whereas the protrusions or the -- this portion is referred to as the gyri.

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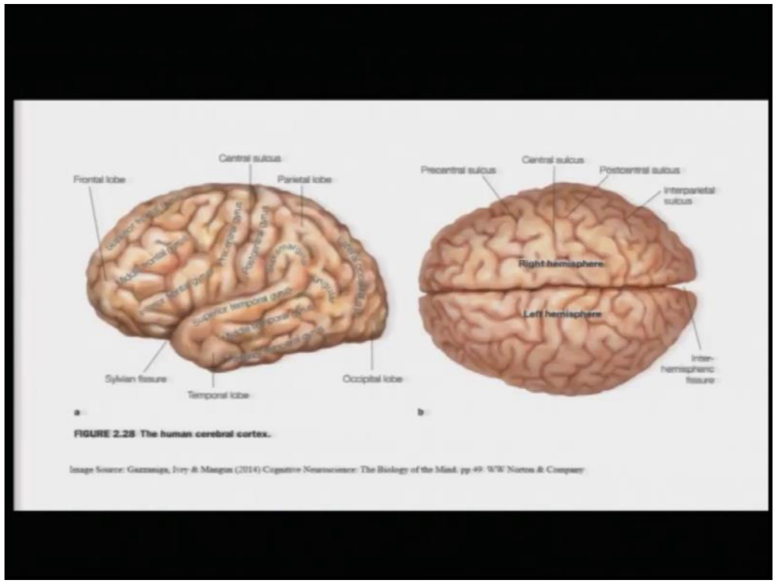

So, you can see that these are the main protrusions, which are so named. So you have a precentral sulcus, you have the central sulcus which almost runs through the middle of the brain.

Then there is post central. Then there is intraperitoneal, which is somewhere near the region where the parietal lobes are. And then, there is this inter-hemispheric fissure, which is basically a huge gap between the two halves of the brain or the two hemispheres of the brain. Then, you can also look at these protrusions, basically the top portions between these ridges. These are referred to as gyri.

And these gyri have their very specific names. We will need to remember these names. And we will kind of keep revisiting these things as we go further.

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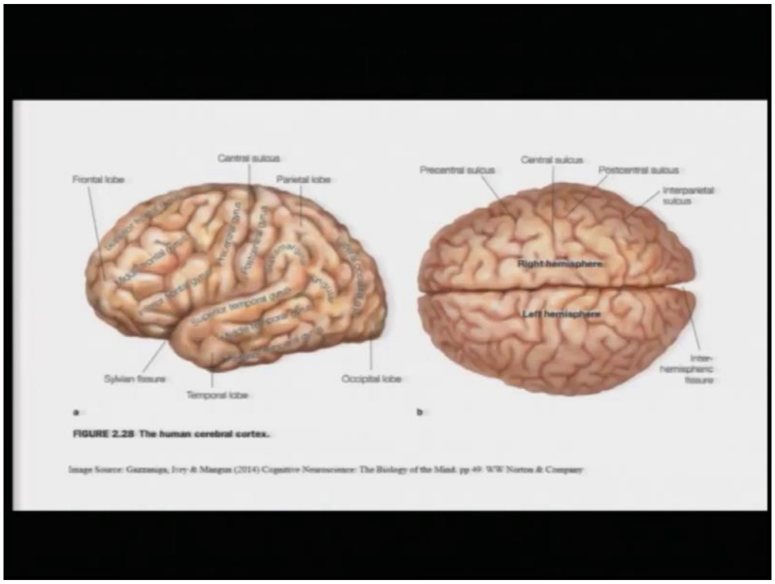

So, you can see that there is the superior temporal gyrus, there is a supramarginal gyrus, angular gyrus, lateral occipital gyrus, there are many of them here, superior frontal gyrus, middle frontal gyrus and so on. So this is something which you will need to remember and we'll keep coming back to this as we go further.

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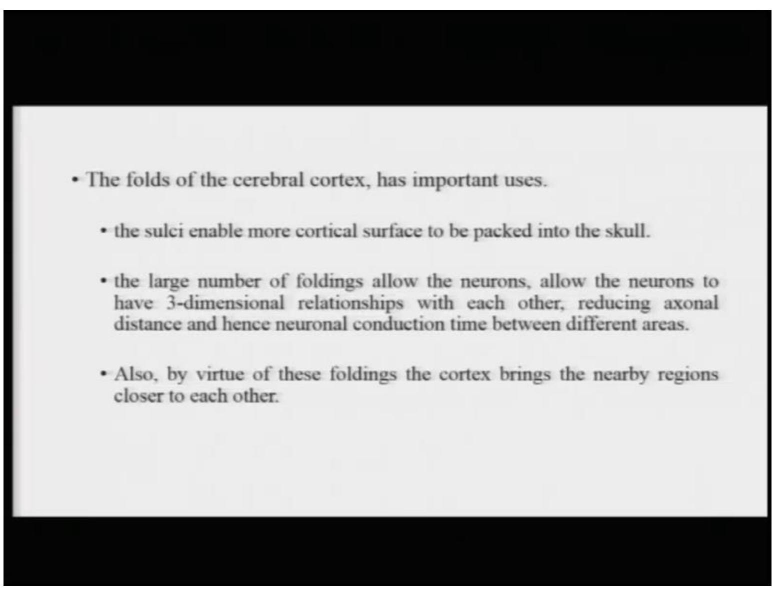

Now, the folds of this cerebral cortex, these ridges and all. They have a very important use. They have, in fact, several important uses. The sulci, or these, these folds basically enable more cortical surface to be packed into the skull. It's like a sheet which has been convoluted and just wrapped into, this fine, but small skull of ours. So, the idea is that this allows several billions of several neurons to be packed within the same area and which might in a sense contributes to the processing capacity and something that -- something that differentiates the human brain from some of the other mammalian brains.

These large numbers of holdings allow the neurons to have sort of three dimensional relationships with each other, basically being close to each other, reducing the axonal distance and also hence, reducing the neuronal conduction time that it takes to send signals between different neurons across different areas.

This is also something very, very important, if you think of it that say for example, if a particular stimulus has to be processed and several aspects of the stimulus have to be processed, and the neurons that are responsible for processing, different aspects of the same stimuli are located not at all at once but into different areas of the brain. All of them because of this convolutions because of this slightly, tightly packed arrangement of the neurons in the cerebral cortex.

The signals reach almost in no time to all of these different areas and processing can operate fairly quickly. Also, by virtue of these foldings in the cortex, the nearby regions, that process different aspects of stimuli can be fairly closer to each other than say, for example, if it were a spreadsheet, you can imagine of a bedsheet kind of a thing, it will be slightly further apart from each other to the point A from point B will be further off from each other unless if it is folded and they are closer to each other.

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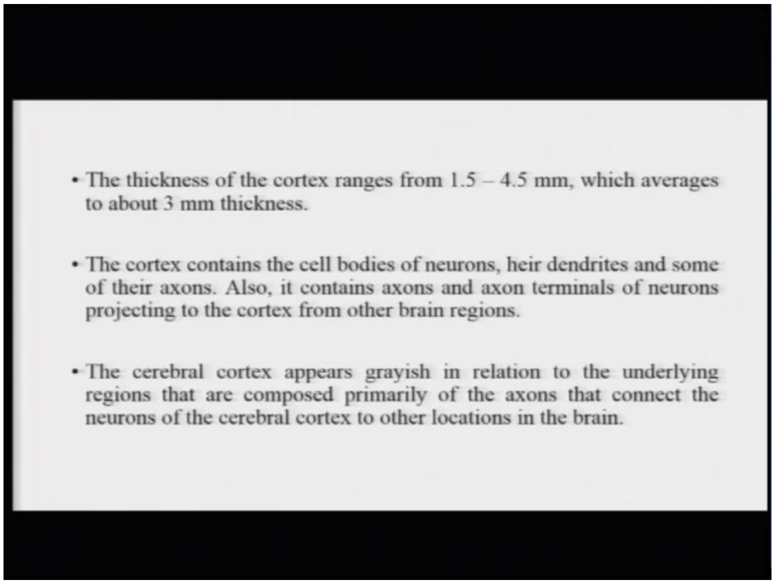

Now, the thickness of this tissue, the thickness of the cortex ranges from between 1.5 to 4.5 millimeters. And it sort of averages of -- averages up to about three millimeters thickness. This cortex basically is composed of cell bodies of neurons, their dendrites and some of their axons. Also it contains axons and axon terminals of neurons, which are projecting to the cortex from different regions of the brain. The cerebral cortex, basically if you sort of are looking at a live brain at in front of you, it would appear grayish in relation to the underlying regions which are mostly whitish in color.

Now, this color or this gray tint is basically because this cerebral cortex is composed primarily of the axons that are connecting the several neurons of different regions of the cerebral cortex with each other.

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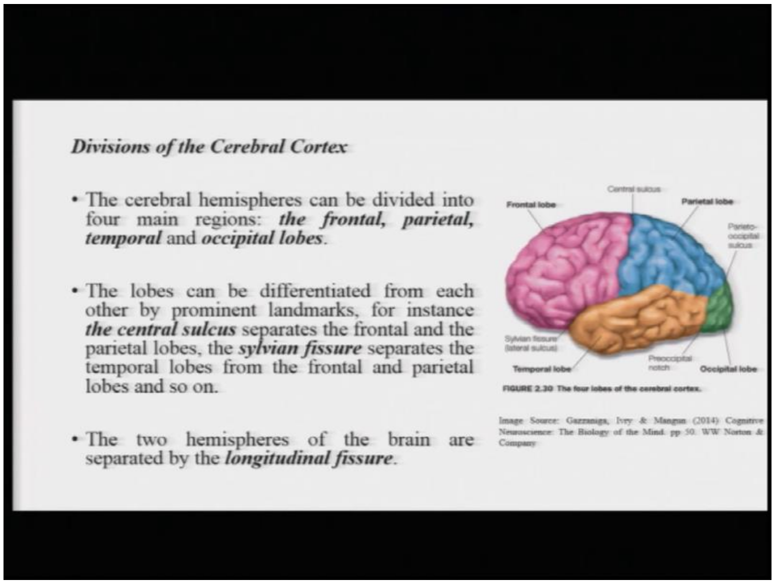

Now, let us look at the broader organization or broad divisions in the cerebral cortex. Now, you can look at this figure here. This front portion or the anterior portion of the cerebral cortex is referred to as the frontal lobe. Beyond the posterior to the central sulcus is the parietal lobe, which sort of extends up till the parietal occipital sulcus, which marks the beginning of the occipital lobe. And then, there is this sulcus called a preoccipital notch, which sort of separates the occipital lobe from the temporal lobe. And then you have this sylvian fissure which sort of marks the upper boundary of the temporal lobe.

Now, these are four main lobes, or four main broad regions of the cerebral cortex. Also, you have to remember that these things exist in both the hemispheres. So we are looking at left hemisphere here, but the parallel structures, the same kind of organization is existing in the right hemisphere as well. Now the cerebral -- so this is basically one of the first things that you will need to remember.

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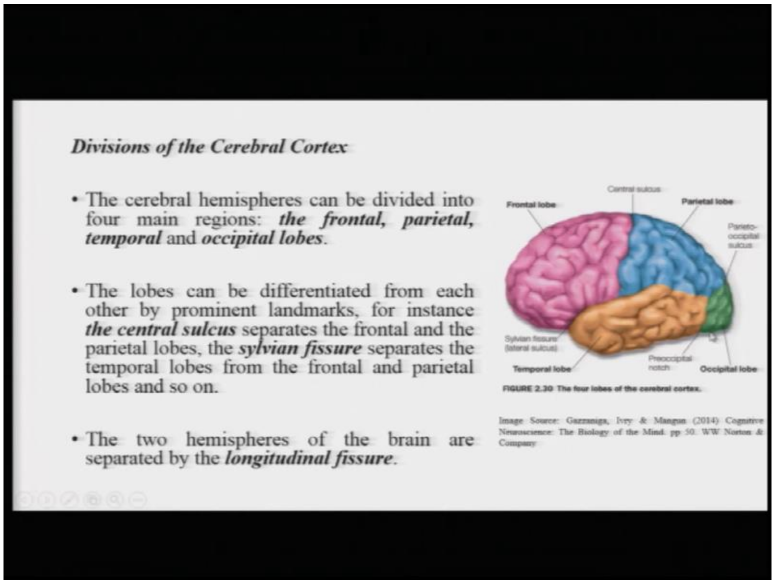

You will need to remember the locations of each of these lobes and how they are defined by these different sulci.

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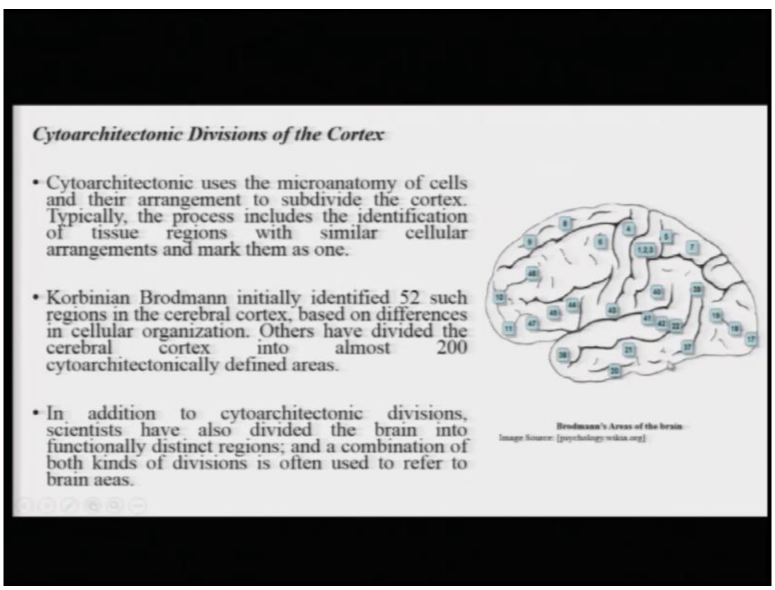

Now, there are other ways of dividing the cortex into separate regions. One of the methods is referred to as cytoarchitectonics. Now cytoarchitectonics basically uses the microanatomy of the cells and their arrangement to subdivide the cortex into different regions, typically based on the identification of the cell types, and based on the kind of inputs they are getting and the kind of outputs they are sort of coming up with. So Korbinian Brodmann, if you remember the name, Korbinian Brodmann basically initially identified 52 such regions in the cerebral cortex based on differences in cellular organization. And the map that he sort of gave is still used rather extensively and the areas are referred to as Brodmann area.

So, you can see here, there are around 52 different Brodmann areas. And some of these, some of the areas or the regions of the brain that we will be talking about in detail going further are typically referred to as let us say, this area here is Brodmann's area-44 or say for example, this area here is Brodmann's area-17, which basically is responsible for visual processing lays in the occipital lobe and so on.

So, moving further, when we are talking about different mental processes, you will see me referring to particular areas by their name as per the Brodmann classification, Korbinian Brodmann's classification, or by a specific it you'll coordinate with respect to the play. So, in addition, so, this is something, which also you'll probably need to remember going further. Now, in addition to the cytoarchitectonic divisions, which as I said were based on the cellular organizations.

There are other ways also in which you can divide the brain. People have been looking at brain function for a long time now. And one of the things that people obviously have figured out is that the human brain can also be divided on the basis of the functionality that each of the regions of the brain has. Now let's look at that.

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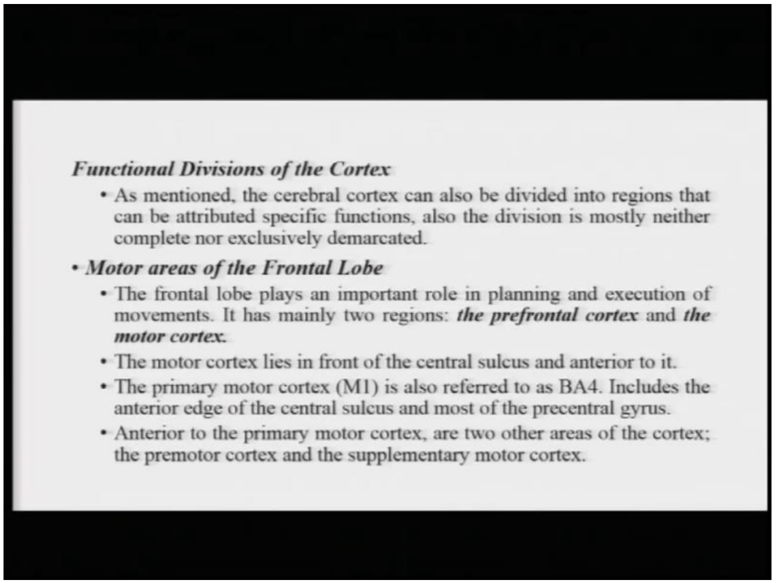

With respect to the functional division of the cortex, we can basically sort of talk about certain specific regions, which at the same time perform very similar functions. So let us look at, say for example, the motor areas, which lay in the frontal lobe. The frontal lobe is a very, very important, it’s probably the most important aspect of the entire brain, because it plays a very important role in a lot of higher mental functions.

One of them being planning and execution of movements. Any movement that I'm doing or you're doing for that matter is basically initiated in the motor cortex of the brain. And the motor cortex can be thought of as two major reasons. First is the prefrontal cortex in front and the second is the motor cortex. You can look at the diagram here.

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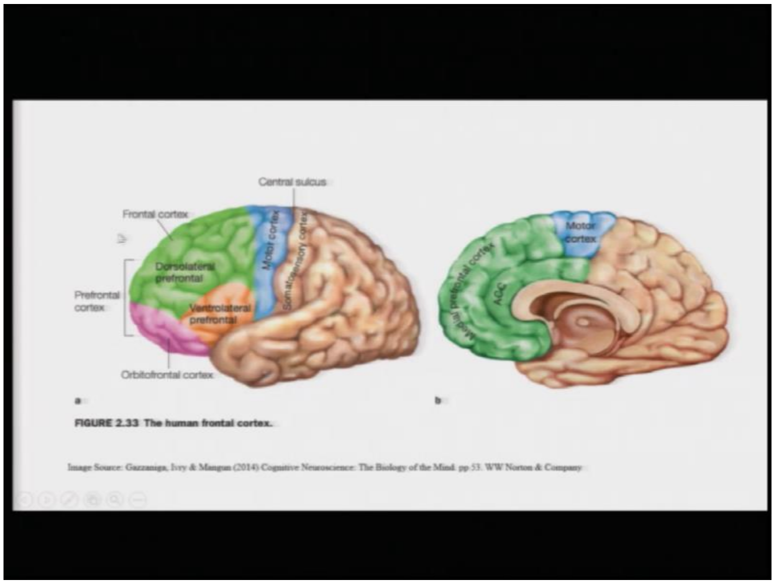

This is basically the prefrontal cortex, everything anterior to the blue region called the motor cortex. This is the prefrontal cortex. There are three at least a major regions prefrontal, dorsolateral prefrontal, ventral lateral prefrontal, and orbital frontal. And then there is the medial prefrontal cortex as well. And then, you have the motor cortex which is marked by the central sulcus as the posterior and extends a little bit up to the boundaries of the dorsolateral and the ventral lateral prefrontal cortex. So, this is basically, these two are basically the motor areas which are responsible for planning and execution of movements.

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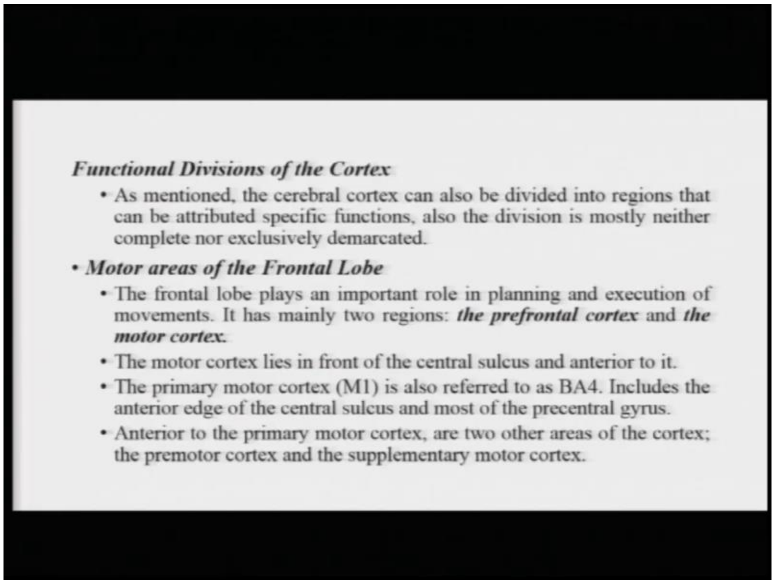

Now, the primary motor cortex, which can also be referred to as m-1 is typically referred to as Brodmann's area 4. And it basically includes the anterior edge of the central sulcus, the front portion of the central sulcus. And then most of the precentral gyrus. Most of this region, as I showed here, most of the precentral gyrus. Now, anterior to the primary motor cortex are two other areas of the cortex, which are the premotor cortex, and the supplementary motor cortex.

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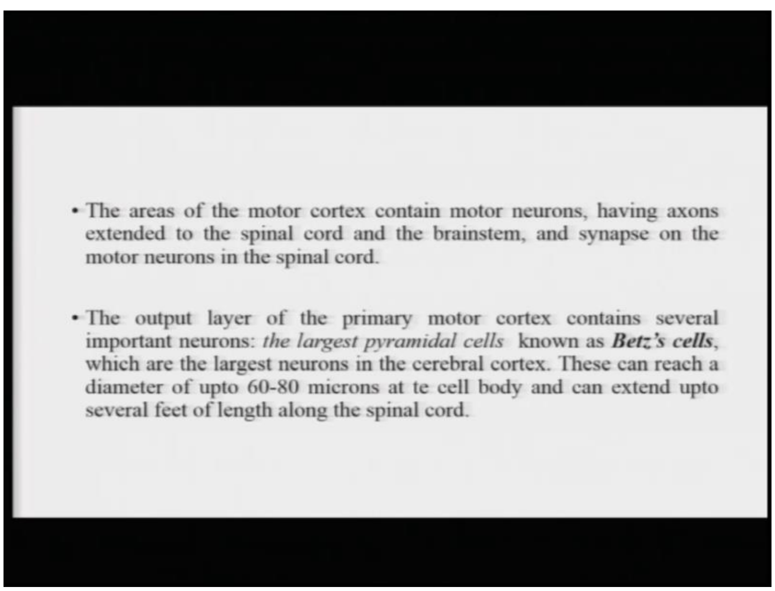

And these areas basically have these motor neurons, which have axons in extending to the spinal cord and the brain stem. And these motor neurons basically synopsis and the motor neurons in the spinal cord. Now the output layer of the primary motor cortex basically contains several very important neurons which are responsible for controlling coordination of movements.

One of the examples would be the largest pyramidal cells known as the Betz’s cells. And the Betz’s cells are the largest neurons in the entire cerebral cortex. These can reach up to a diameter of 60 to 80 microns with respect to the cell body, and their axons can extend up to several feet of length down the spinal cord.

So, this is the region, we will talk about all of this in a lot of detail. But this is a region which is primarily concerned with planning, execution of movements that the human body does. Now we can talk a little bit about the prefrontal cortex, the area in front or anterior to the motor cortex. Now the anterior regions of the frontal lobe are referred to as the prefrontal cortex, then they are basically responsible for complex mental functions.

So just planning, organizing executive behaviors such as selection of a task, initiation of a task, and choosing several responses within a task, all of those kind of things, which typically involve integration of information overtime is basically handled by this prefrontal cortex. People with damage to the prefrontal lobes or this prefrontal cortex or any region of this prefrontal, a wide range of difficulties. They might say, for example, experience difficulty in starting an action. They might experience a difficulty in modulating an action or stopping the course of an action.

So, some of these difficulties are very common to be observed when people are suffering from different kinds of damage to the prefrontal cortex.

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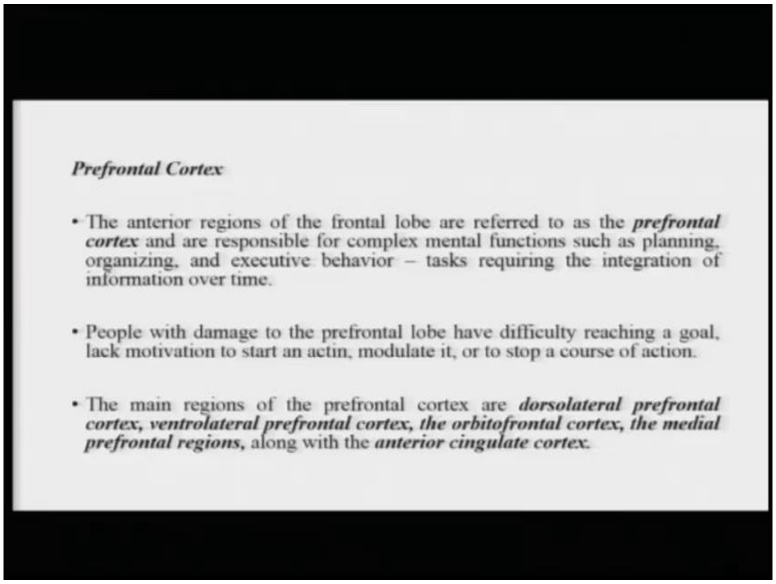

One of the examples that I can sort of also remember from discussing some of the other cases, in some of the other classes is the example of this gentleman called Phineas Gage. And this is a very famous example in neuroscience and neuropsychology. Phineas Gage was a railroad worker at some point. And what happened was that there was an unfortunate accident once while he was working on the tracks. And basically the task was to side sort of put dynamite and detonate the rocks for making way for tracks to be laid on.

And what happens is by virtue of, by some unfortunate accident, there was this iron rod that enters Phineas Gage's skull through the cheekbone and goes through the skull. And it damages part of the prefrontal lobe, part of the prefrontal cortex. And eventually what happens is while the individual survives for a few years, what it does is it causes significant changes in the person's personality, his general behavior, it's a social behavior and so on. So that was one of the early and very very important cases in neuropsychology, which will sort of if you look into YouTube or sort of Google it a little bit, you will find a lot more about this.

But that also sort of tells us that the prefrontal cortex is very important for an individual's social behavior, for an individual's overall personality and so on. So that is also something that is fairly important and I will probably want you to remember that. Now, the main regions of the prefrontal cortex, as I already told you are the dorsolateral prefrontal cortex, ventral lateral prefrontal cortex, orbitofrontal cortex, and then the medial prefrontal cortex along with the anterior cingulate cortex. Again, you do not really have to mug up all of these names. But as and when they come, it will be great if you know, say for example, roughly within the brain where these regions are specifically aligned.

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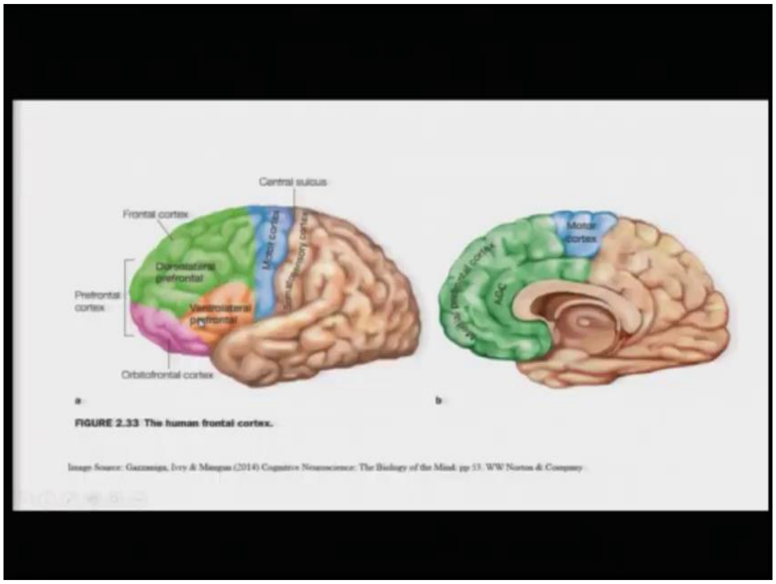

So again, just to show you, this is the dorsolateral prefrontal, ventral lateral prefrontal, orbitofrontal, this is the medial prefrontal and this is the anterior cingulate cortex, all of which form part of the prefrontal cortex as I am saying.

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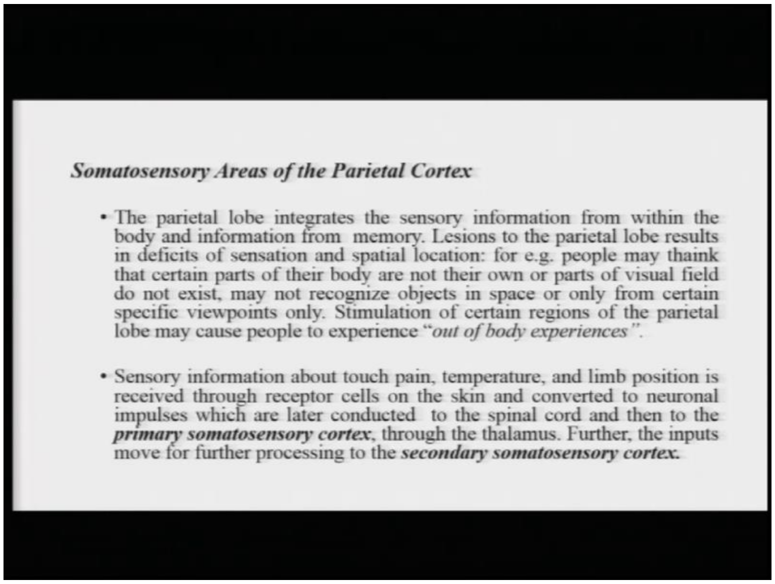

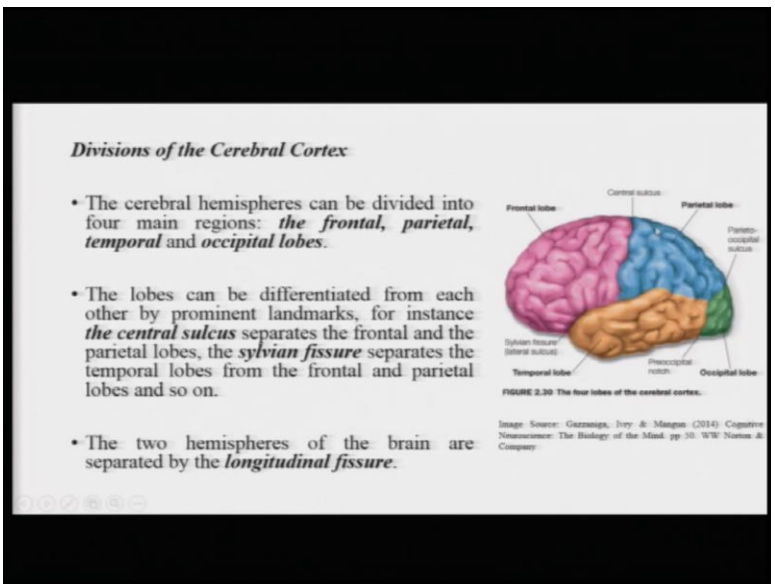

Now let us talk about the somatosensory areas of the parietal cortex at the back. If you remember, this is basically the parietal lobe or the parietal cortex, we have to talk about the somatosensory region, which is typically this particular region here. This is referred to as the somatosensory cortex.

Let us talk a little bit about this one. Now, the parietal lobe, basically what it does is it integrates the sensory information from within the body and the information from memory. Okay, say for example, if you are performing any complex movements. If you want to navigate to go to some place, or if you are sort of experiencing different kinds of stimuli from the environment, this is a region of the brain that will try and integrate that information.

And lesions to the parietal lobe may result in different kinds of deficits, especially with respect to spatial navigation and spatial location. For example, a lot of people may who have parietal damage or damage in any area of the parietal lobe may think that certain parts of their body are not their own. So the ownership kind of goes away, because the parietal lobe is, as I said integrating information from within the body.

So when I am moving my hand, there is something, there is a region called the parietal lobe, or there is a region in the parietal cortex, which is telling me the exact position of my hand as and when I am moving it. It is keeping me connected to my extremities in one sense. And many many tasks which involve this, say for example, if you are playing a sport or if you are performing a dance act or something, this is very very important, knowing exactly where each part of your body is, is obviously very important.

And the parietal lobe is something that sort of helps you do it. Now, other kind of deficit that may arise for people with different aspects of parietal damage is that they might not be able to recognize objects or may be able to recognize objects only from certain viewpoints. Sometimes say for example, people have shown that if you stimulate the regions in the parietal cortex, it might lead the people to experience something that is called out of body experiences.

Now out of body, how do the out of body experiences arise? You might have heard several different stories about it, but typically what would happen is that the connection or the feedback that is coming from the different extremities would be disconnected, sort off. And you will feel that you are out of your body and not be getting these sensations.

Now, sensory information about different kinds of stimuli like touch, pain, temperature, and limb position is basically received through the receptor cells on the skin. These receptor cells basically convert these sensations to neuronal impulses, which are sort of sent via the spinal cord, via the thalamus to what is called the primary somatosensory cortex. And this primary somatosensory cortex can later relay this input to what is the preceding area called secondary somatosensory cortex, where a more detailed, and more sophisticated processing of the same stimulus will proceed.

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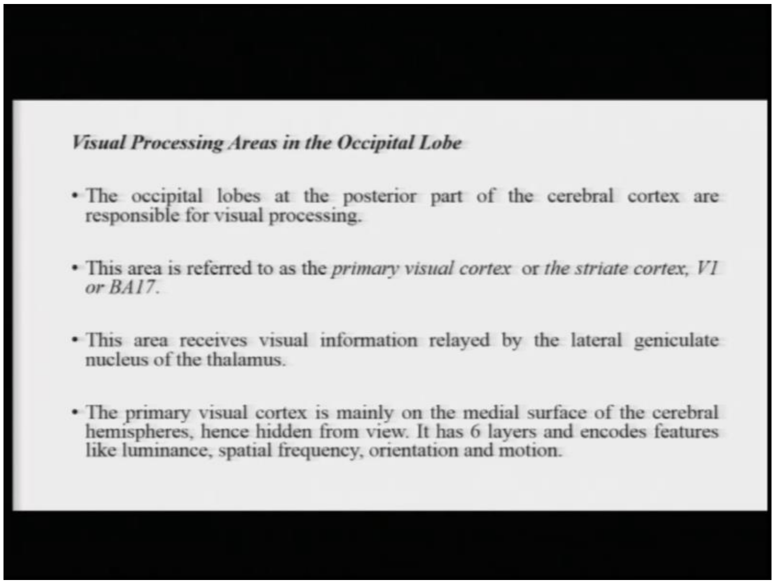

Other important areas are the occipital lobe for example. The occipital lobe is the posterior most part of the cerebral cortex at the back. If you remember, there was this preoccipital sulcus at the back of which the occipital lobes lie. So this is the region. This is the occipital lobe. This is the region that I am going to be talking about.

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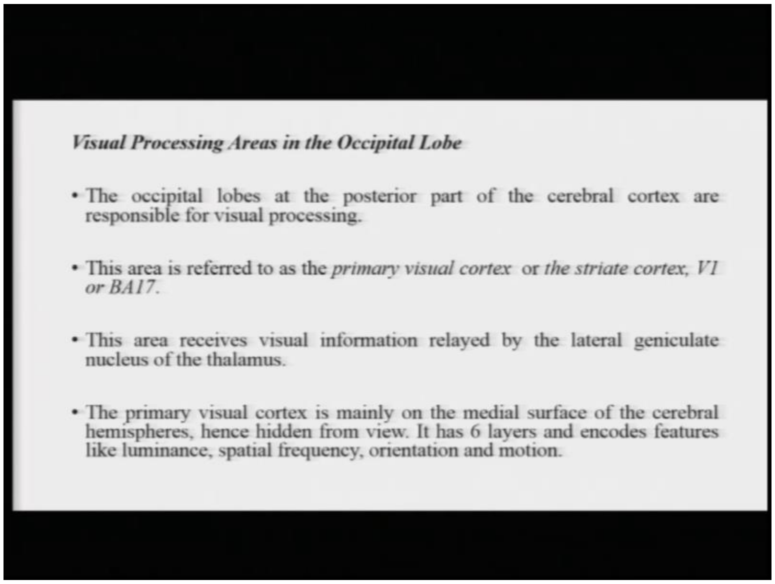

Now, this occipital lobe is mainly concerned with various aspects of visual processing. This is referred to as the primary visual cortex or the striate cortex. In Brodmann's nomenclature, this is basically referred to as Brodmann's area-17 as I showed you. Now this area basically what it does is, it receives the visual information related through the eyes. How is this happening, is that the eyes, basically the processing, the initial processing happens in the retina at the back of the eye in the retina.

The retina basically, there are nerves coming out of the retina, which is basically the optic nerve. The optic nerve released information to the lateral geniculate nucleus of the thalamus. And via the thalamus the information goes or is projected towards this area, which is your primary visual cortex or the striate cortex.

Now, this primary visual cortex is once the information reaches here just let us talk a little bit about this. The primary visual cortex is mainly on the medial surface of the cerebral hemispheres. So it is not something that you can sort of see, and from the outside is something which is between the two hemispheres hidden from you. But it has six different layers. And it is it encodes different features like luminance, spatial frequency, color, orientation and motion. And there are these different layers of neurons which are sort of specialized in each of these functions.

Once the initial processing of a particular stimulus has happened, all of this information needs to be integrated in the association areas of the brain, where a common percept is, as created and you can say, for example, see a red apple or a yellow mango or something like that because but the initial processing in the visual cortex is very discreet, and is sort of done in, in terms of different features.

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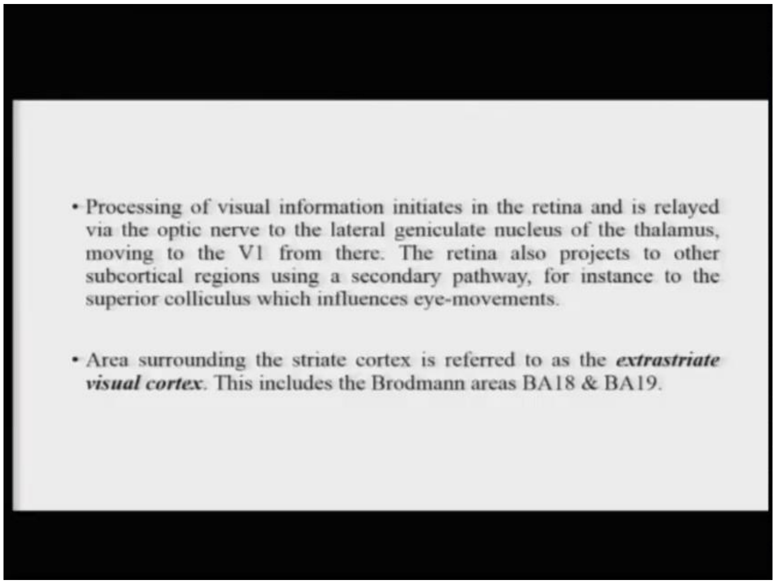

Now, processing of this is one this is something that I have already told you. So I am just going to repeat myself a little bit. So, processing of visual information is initiated in the retina is relayed via the optic nerve to the lateral geniculate nucleus of the thalamus and moves to area V1 or BA-17 from there. The retina by the way also projects to other subcortical regions using a secondary pathway. For instance, say for example, there are projections from the retina to the superior colliculus. If you remember we have talked about this in the earlier section.

And the superior colliculus is basically one of the regions that is involved in controlling of eye movements, orienting of the eyes towards where more information is to be found. Now, areas which are surrounding the striate cortex is referred to as the extra-striate cortex and basically includes Brodmann's areas 18 and 19.

Again, this is all I am sort of just giving you a bit of a preview about the general organization in the brain. All of these areas, all of these details will be discussed in much more detail when we are talking about specific aspects of mental processes.

We can, we have talked about the occipital lobe, we have talked about the frontal lobe, we have talked about the parietal lobe. We can also talk now about the temporal lobe.

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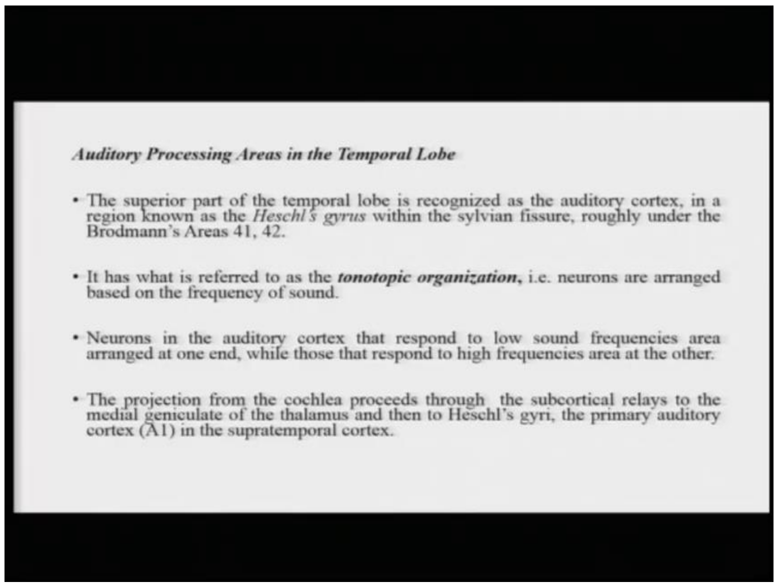

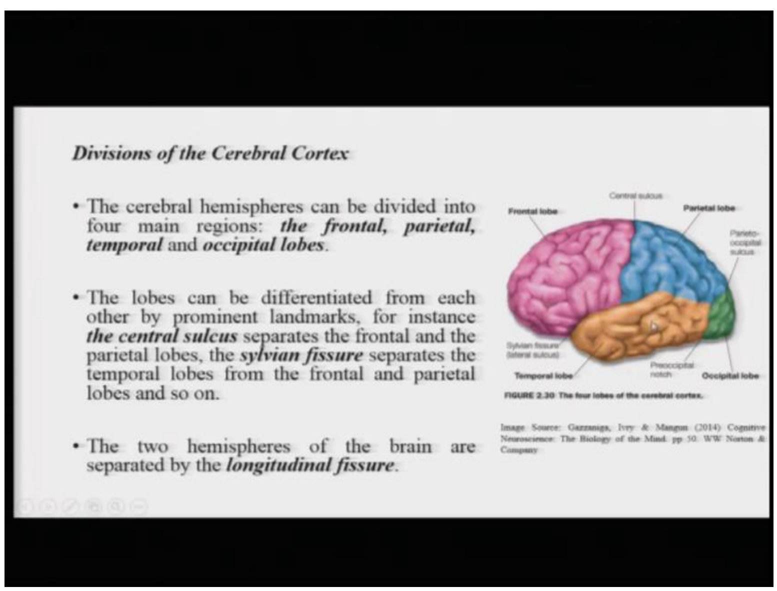

The temporal lobe just right above your ears, this region here. This is the region of the temporal lobe. This region here is mainly basically concerned with the processing of auditory information.

And this is basically also a region called the region called the Heschl's gyrus, which is within the Sylvian fissure, and roughly Brodmann's area-41 and 42 sort of marked the boundaries here.

Now, the organization of neurons in the auditory cortex or in the temporal lobe is basically referred to as a tonotopic organization, which basically means that neurons are arranged as per the frequency of the sounds that they are going to process. So neurons in the auditory cortex that would respond to low frequency sounds would be at one end. And neurons that would respond to high frequency sounds would be at the other end.

So typically, you can see that this is let us say, if this is the temporal lobe, the neurons are arranged in this temporal lobe, as per the frequency of sound that they would respond to or process. Now, how does this region receive its inputs? Now the projection from the cochlea from the inner ear basically proceeds through subcortical release to the medial geniculate nucleus of the thalamus. And then it kind of from the thalamus is projected with Heschl's gyri or the primary auditory cortex, which lies in the supratemporal or the above or the upper region of the temporal lobe.

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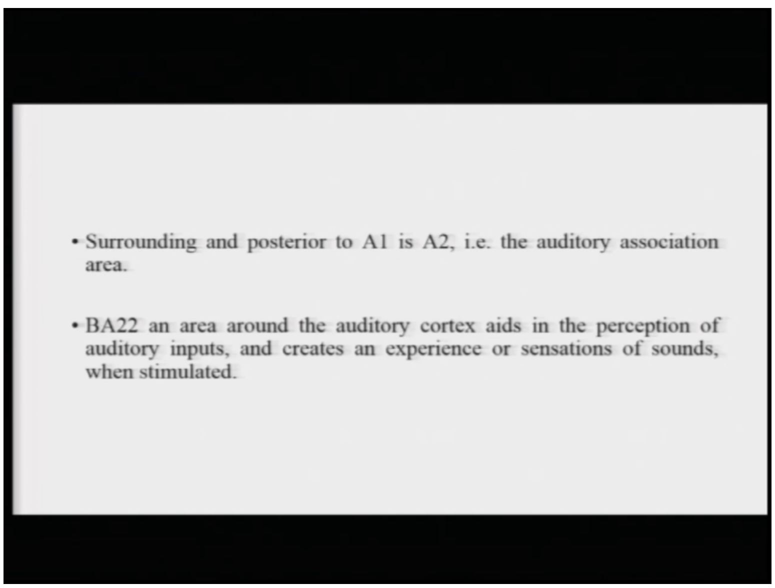

Now, surrounding and posterior to this area, primary auditory cortex or even is A1 to A2, which is also referred to as the auditory association area. And which sort of performs a slightly higher level processing on the sound input. Typically, say for example, if the sound is there, you sort of initially analyze the sound. And then suppose you want to recognize, what song was that or whose name did I hear or what kind of stimulus was that, those kinds of processing would be done in the auditory association areas.

Now Brodmann area-22 is, which is an area around the auditory cortex aids in perception of auditory inputs and creates an experience or sensation of sounds when it is stimulated. So this is broadly the region, which sort of allows us to experience these different sounds.

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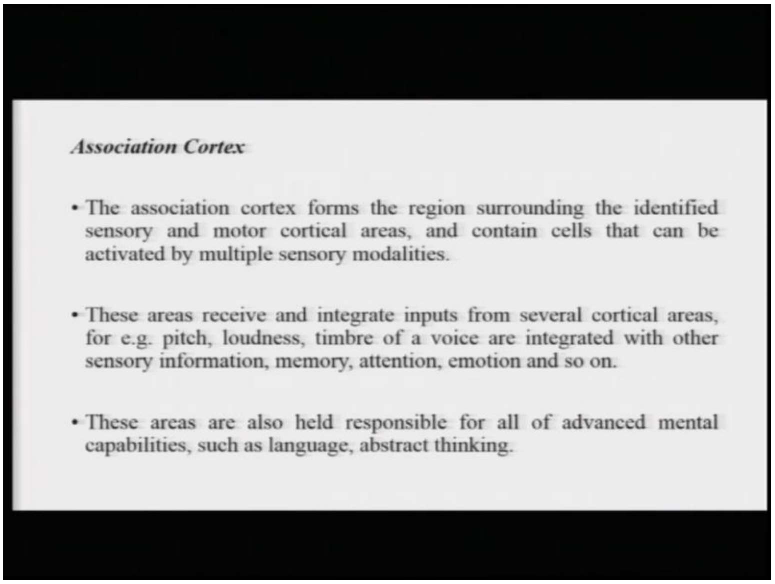

Now, finally, we can talk about the association cortex. The association cortices basically are the from the regional surrounding, the identified sensory and motor cortical areas. And they basically contain cells that can be activated not by just the visual modality or just the auditory modality, but by multiple sensory modalities, vision, auditions and gustation olfaction, proprioception which is pressure and so on.

So many of these things together will activate cells or neurons in these regions. And these regions basically receive and integrate input from several vertical areas. Say, for example, pitch, loudness and timbre of a voice are integrated with sensory information like memory, attention, emotion and so on.

So, for example, you have to remember, you know, if you have to identify the sound, or identify a particular song, multiple levels of analysis will be needed. And all of that analysis will typically happen in the analysis will be needed in the association cortices.

Now, the association cortices are also held responsible for all kinds of advanced mental capabilities such as abstract thinking, language, planning of activities and so on, because they have access to all of this information from these different sensory and motor vertical areas. And this information can be processed further integrated, and manipulated to sort of give rise to very complicated things such as language and abstract thinking. We will talk about all of this in much more detail as we go ahead.

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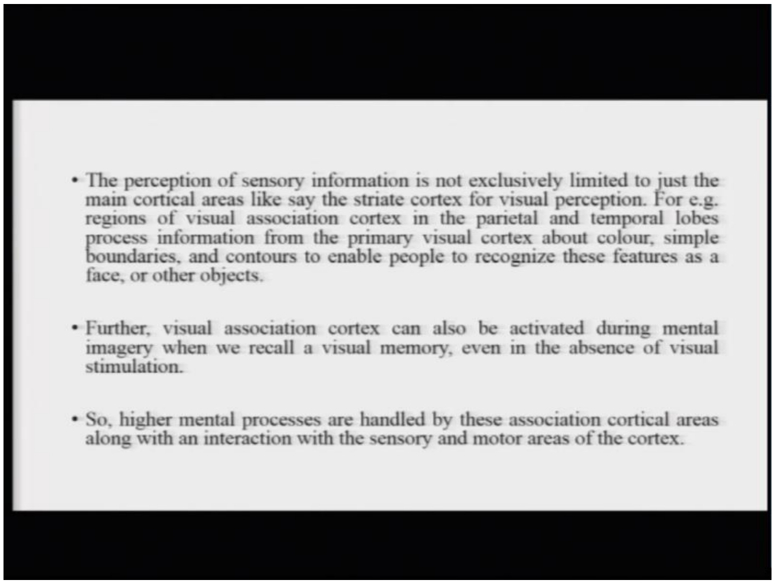

Now say for example, let us take some examples. The perception of sensory information is not really exclusively limited to just the main cortical areas like just, let us say, the striate cortex or visual perception or the auditory, primary auditory cortex or auditory perception. Typically, the way we interact with our surroundings, typically the way we interact with our visual stimuli, basically is that, we have to integrate information coming from several areas.

Say for example, if you are listening to me talking to you, there is obviously processing going on in the visual areas which are showing you the details in the video, you are hearing me. So there is also some processing going on the auditory areas.

You are probably making sense of what I am saying and that is basically being done in, in the association areas or areas which are sort of integrating this information over time. So, one of the things that you sort of also need to keep in mind is, how is all of this, all of this different kind of integration really happening?

And this is something which is very very important and is taken care of by the association cortices. Further, visual association cortex can also be activated through things like, say for example, I was mostly talking about receptive activation, but it could be that, you are sitting somewhere and you are just thinking of a nice place where you would like to have your vacation on. Say, for example, if you are exercising different kind of mental imagery, that I want to be at a place where there is a river, there is a valley, there are green plants and there is sound of water coming in.

As soon as you sort of going through this mental imagery, it is observed that different areas, which or different areas of the brain are activated by different aspects of this imagery. So, you might already be activating the visual areas and the auditory areas because I mentioned the sound of water, and so on.

So this is primarily in a nutshell, the basic processing in the auditory association, in these association areas or the association cortices. So, this is, say for example, this is basically the idea where we can say that the higher mental processes are handled by these association cortices. And they basically modulate or govern the interaction between the sensory and motor areas of the brain.

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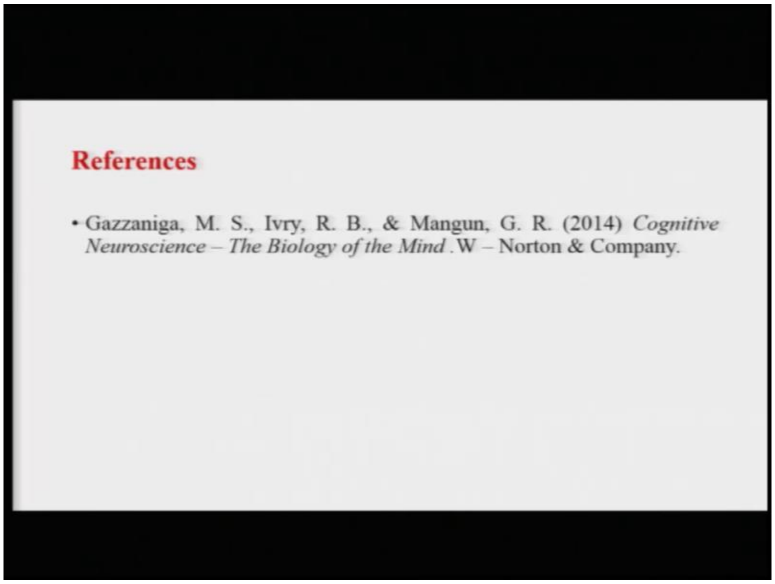

So I have sort of given you a bit of I have given you a bit of a preview of the generic organization in the brain in terms of the lobes, in terms of the functional areas that are responsible for different mental functions. We have also sort of looked at the entire nervous system in some detail. And this is basically one of the things that we will be doing in this course. We will be going into a lot of detail about how this generic setup is involved in performing, on helping us perform the very specific mental functions that we will be talking about. Thank you.